Taylor Larrechea
Dr. Schiffbauer
PHYS 231 HW 2
2-4-18

Ch. 3

#'s: 2, 8, 18, 29, 30, 32, 36, 45, 51, 59, 60

Problem 2

i.)

$E = 2.5\times10^5\ V/m \qquad v = 2.2\times10^6\ m/s$

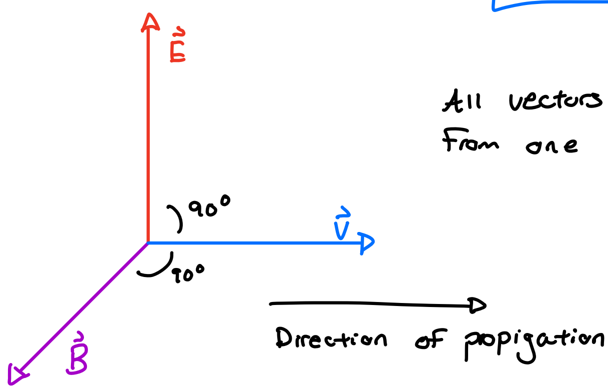
$$\frac{q}{m} = \frac{V_0^2 \tan\theta}{E\ell} = \frac{E\tan\theta}{B^2\ell}$$

$$\frac{V_0^2\tan\theta}{E\ell} = \frac{E\tan\theta}{B^2\ell} \ : \ \frac{V_0^2}{E} = \frac{E}{B^2} \ : \ V_0^2 = \frac{E^2}{B^2} \ : \ V_0 = \frac{E}{B} \ : \ B = \frac{E}{V_0} = \frac{2.5\times10^5\ V/m}{2.2\times10^6\ m/s}$$

$B = 0.113\ T$

$$\boxed{B = 0.11T}$$

ii.)



All vectors are perpendicular from one another.

Problem 8

$V_T = 1.3\ mm/s \quad \rho = 900\ kg/m^3 \quad \eta = 1.82\times10^{-5}\ kg/m\cdot s$

i.) $r = 3\sqrt{\frac{\eta v_t}{2g\rho}}$

$$r = 3\sqrt{\frac{(1.82\times10^{-5})\,kg/ms\,(0.0013\ m/s)}{2(9.8\ m/s^2)(900\ kg/m^3)}} = 3.0\times10^{-6}m$$

$$\frac{kg}{\cancel{m}s}\cdot\frac{\cancel{m}}{s} = \frac{kg}{s^2} \qquad \frac{\cancel{m}}{s^2}\cdot\frac{kg}{m^{\cancel{3}2}} = \frac{kg}{s^2m^2} \qquad \frac{\frac{kg}{s^2}}{\frac{kg}{s^2m^2}} \qquad \frac{\cancel{kg}\cancel{s^2}m^2}{\cancel{s^2}\cancel{kg}} = m^2$$

$$\boxed{r = 3\ \mu m \text{ or } 3.0\times10^{-6}m}$$

ii.) $m = \frac{4}{3}\pi r^3\rho \qquad r = 3.0\times10^{-6}m \qquad \rho = 900\ kg/m^3$

$$m = \frac{4}{3}\pi(3.0\times10^{-6}m)^3(900\ kg/m^3) = 1.017\times10^{-13}\ kg \Rightarrow 1.02\times10^{-13}kg$$

$$\cancel{m^3}\cdot\frac{kg}{\cancel{m^3}} = kg$$

$$\boxed{m = 1.02\times10^{-13}\ kg}$$

iii.) $V_T = \frac{mg}{b} \qquad V_T = 0.0013\ m/s \qquad m = 1.02\times10^{-13}kg$

$$b = \frac{mg}{V_T} = \frac{(1.02\times10^{-13}kg)(9.8\ m/s^2)}{(0.0013\ m/s)} = 7.689\times10^{-10}\frac{kg}{s} \Rightarrow 7.69\times10^{-10}\frac{kg}{s}$$

$$\frac{kg\cdot\cancel{m}/s^{\cancel{2}}}{\cancel{m}/\cancel{s}} = \frac{kg}{s}$$

$$\boxed{b = 7.69\times10^{-10}\ kg/s}$$

Problem 18

$$\lambda_{max} T = 2.898 \times 10^{-3}\, m \cdot K \qquad T = \frac{Q}{\lambda} \qquad Q = 2.898 \times 10^{-3}\, m \cdot K$$

i.) $\lambda = 1.50 \times 10^{-14}\, m$

$$T = \frac{Q}{\lambda} = \frac{2.898 \times 10^{-3}\, m \cdot K}{1.50 \times 10^{-14}\, m} = 1.93 \times 10^{11}\, K$$

$$\boxed{T = 1.93 \times 10^{11}\, K}$$

ii.) $\lambda = 1.50 \times 10^{-9}\, m$

$$T = \frac{Q}{\lambda} = \frac{2.898 \times 10^{-3}\, m \cdot K}{1.50 \times 10^{-9}\, m} = 1.93 \times 10^{6}\, K$$

$$\boxed{T = 1.93 \times 10^{6}\, K}$$

iii.) $\lambda = 640 \times 10^{-9}\, m$

$$T = \frac{Q}{\lambda} = \frac{2.898 \times 10^{-3}\, m\, K}{640 \times 10^{-9}\, m} = 4528.13\, K$$

$$\boxed{T = 4530\, K}$$

iv.) $\lambda = 1\, m$

$$T = \frac{Q}{\lambda} = \frac{2.898 \times 10^{-3}\, m \cdot K}{1\, m} = 2.898 \times 10^{-3}\, K$$

$$\boxed{T = 2.9 \times 10^{-3}\, K}$$

v.) $\lambda = 204\, m$

$$T = \frac{Q}{\lambda} = \frac{2.898 \times 10^{-3}\, m \cdot K}{204\, m} = 1.42 \times 10^{-5}\, K$$

$$\boxed{T = 1.42 \times 10^{-5}\, K}$$

Problem 29

number of allowed states,

$$dN = \frac{1}{8} 4\pi r^2\, dr \qquad \text{P. 312}$$

Surface area of sphere

$r + dr$

$$dN = \frac{1}{8} 4\pi r^2\, dr \qquad r \equiv \sqrt{n_x^2 + n_y^2 + n_z^2}$$

$$\omega = \frac{\pi c}{L} r$$

$$\frac{\omega L}{\pi c} = r$$

$$\frac{\omega^2 L^2}{\pi^2 c^2} = r^2$$

$$\frac{dr}{df} : \quad r = \frac{(2\pi f)^2 L^2}{\pi^2 c^2} = \frac{4\cancel{\pi^2} f^2 L^2}{\cancel{\pi^2} c^2}$$

$$r^2 = \frac{4 f^2 L^2}{c^2} \qquad r = \frac{2FL}{c}$$

$$\frac{dr}{df} = \frac{2L}{c}$$

$$dr = \frac{2L}{c}\, df$$

$$dN = \frac{1}{8} 4\pi r^2\, dr$$

$$= \frac{1}{8} 4\pi \left(\frac{4F^2L^2}{c^2}\right)\left(\frac{2L}{c}\right) dF$$

$$= 2\pi \left(\frac{F^2L^2}{c^2}\right)\left(\frac{2L}{c}\right) dF$$

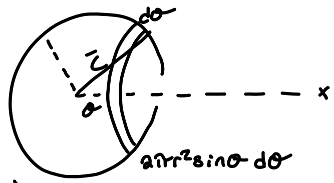
$$= \frac{4\pi f^2 L^3}{c^3}\, df \quad \checkmark$$

$$\boxed{dN = \frac{4\pi f^2 L^3}{c^3}\, df}$$

Problem 30

The component of speed for an E.M wave,

$$C_n = \int_0^r \int_0^{\pi/2} \int_0^{2\pi} c\cos\theta \, dv \qquad dv = r\sin\theta \, dr \, d\theta \, d\phi$$



$\vec{x} = c\cos\theta$

$$C_x = \frac{\int_0^{\pi/2} (c\cos\theta)\, 2\pi r^2 \sin\theta \, d\theta}{\int_0^{\pi/2} 2\pi r^2 \sin\theta \, d\theta}$$

$x = \cos\theta \quad dx = 2\pi r^2 \sin\theta \, d\theta$

$t[0:1] = [0:\pi/2]$

$$C_x = \frac{c\int_0^1 x\,dx}{dx} = c\,\frac{\frac{1}{2}x^2\big|_0^1}{x\big|_0^1} = c\left(\frac{1}{2}\right)$$

$$\mu = \frac{1}{2}(C_x)u = \frac{1}{2}\left(\frac{1}{2}\right)u = \frac{1}{4}u$$

$du(f,T)\Delta A$

$$\boxed{\mu = \frac{1}{4}du(f,T)\Delta A}$$

$$\cancel{m^2} \cdot \frac{J}{\cancel{m^2}\, s} = \frac{J}{s} \checkmark$$

Problem 32

$P = 50{,}000\,W \quad h = 6.626\times10^{-34}\,J\cdot s \quad f = 98.1\times10^{6}\,Hz$

$\text{Intensity} \equiv \dfrac{\text{Power}}{\text{number}} \quad \therefore \quad \text{number} = \dfrac{\text{Power}}{\text{Intensity}}$

$\text{Intensity} \equiv h\cdot f \qquad n = \dfrac{\text{Power}}{h\cdot f}$

$$n = \frac{P}{h\cdot f}$$

$$n = \frac{50{,}000\,W}{6.626\times10^{-34}(98.1\times10^{6}\,s^{-1})} = 7.69\times10^{29}\,\frac{\text{protons}}{s}$$

$$\boxed{n = 7.69\times10^{29}\,\frac{\text{Protons}}{s}}$$

Problem 36

$\lambda = 532 \times 10^{-9} m$ $\phi = 1.95 \ eV$ $P = 2.0 \times 10^{6} W$ $\eta = 10^{-5}$ $P = P\eta$ $P \equiv$ Power applied, $\eta \equiv$ efficiency

$hf = \phi + \frac{1}{2} m v_{max}^2$ $eV_0 = \frac{1}{2} m v_{max}^2$

$hf = \phi + eV_0$

$$V_0 = \frac{hf - \phi}{e} = \frac{h\left(\frac{c}{\lambda}\right) - \phi}{e} = \frac{(6.626 \times 10^{-34} J \cdot s)\left(\frac{3.0 \times 10^{8} m/s}{532 \times 10^{-9} m}\right) - 1.95 eV\left(\frac{1.6 \times 10^{-19} J}{eV}\right)}{1.6 \times 10^{-19} C}$$

$V = \frac{I}{C}$

$V_0 = 0.385 \ V$ $P = V \cdot I$

$$I = \frac{P}{V} = \frac{P\eta}{V} = \frac{(2.0 \times 10^{-3} W)(10^{-5})}{0.385 \ V} = 5.19 \times 10^{-8} A$$

$$\boxed{I = 5.19 \times 10^{-8} A}$$

Problem 45

① $\lambda_{min} = 6.4 \times 10^{-11} m$ ② $\lambda_{min} = 7.2 \times 10^{-11} m$ $e = 1.6 \times 10^{-19} C$ $eV_0 = \frac{hc}{\lambda_{min}}$

$c = 3.0 \times 10^{8} m/s$

$h = 6.626 \times 10^{-34} J \cdot s$

$4.136 \times 10^{-15} eV \cdot s$

$$V_0 = \frac{hc}{e} \frac{1}{\lambda_{min}}$$

For ①: $$V_0 = \frac{(6.626 \cdot 10^{-34} J \cdot s)(3.0 \times 10^{8} m/s)}{1.6 \times 10^{-19} C} \cdot \frac{1}{6.4 \times 10^{-11} m} = 19.4 \ kV$$

For ②: $$V_0 = \frac{(6.626 \times 10^{-34} J \cdot s)(3.0 \times 10^{8} m/s)}{1.6 \times 10^{-19} C} \cdot \frac{1}{7.2 \times 10^{-11} m} = 17.2 \ kV$$

Will only consider ② due to it having the smaller of the two values

$$V = 17.2 \ kV$$

Problem 51

i.) $K.E = h\left(\frac{c}{\lambda}\right) - h\left(\frac{c}{\lambda'}\right)$ $\qquad K.E = hf - hf'$ $\qquad f = \frac{c}{\lambda}$

$c = \lambda f$

$$= hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right)$$

$$= hc\left(\frac{\lambda' - \lambda}{\lambda\lambda'}\right)$$

$$= hc\left(\frac{\Delta\lambda}{\lambda\lambda'}\right)$$

$$= \frac{hc\left(\frac{\Delta\lambda}{\lambda}\right)}{\lambda'}$$

$$= \frac{hc\left(\frac{\Delta\lambda}{\lambda}\right)}{\lambda' - \lambda + \lambda}$$

$$\Rightarrow \frac{\frac{hc}{\lambda}(\Delta\lambda)}{\Delta\lambda + \lambda}$$

$$\frac{hf(\Delta\lambda)}{\Delta\lambda + \lambda}$$

$$hf\left(\frac{\Delta\lambda/\lambda}{(\Delta\lambda/\lambda + 1)}\right) \Rightarrow \boxed{K.E = hf\left(\frac{\Delta\lambda/\lambda}{\frac{\Delta\lambda}{\lambda} + 1}\right)}$$

ii.) $P_x: \frac{h}{\lambda} = \frac{h}{\lambda'}\cos\theta + P_e\cos\phi$ $\qquad P_e\cos\phi = \frac{h}{\lambda} - \frac{h}{\lambda'}\cos\theta$

$P_y: \frac{h}{\lambda'}\sin\theta = P_e\sin\phi$ $\qquad P_e\sin\phi = \frac{h}{\lambda'}\sin\theta$

$$\frac{P_x}{P_y}: \frac{P_e\cos\phi}{P_e\sin\phi} = \frac{\left(\frac{h}{\lambda} - \frac{h}{\lambda'}\cos\theta\right)}{\left(\frac{h}{\lambda'}\sin\phi\right)} \qquad \left(\frac{h}{\lambda'}\right)$$

$$\cot\phi = \frac{\left(\frac{\lambda'}{\lambda} - \cos\theta\right)}{\sin\theta}$$

$$\cot\phi = \frac{\left(\frac{\lambda'}{\lambda} - \cos\theta - 1 + 1\right)}{\sin\theta} \qquad (-1+1)$$

$$\cot\phi = \frac{\left(\frac{\lambda'}{\lambda} - 1\right) + (1 - \cos\theta)}{\sin\theta}$$

$$\cot\phi = \frac{\left(\frac{\lambda' - \lambda}{\lambda}\right) + (1 - \cos\theta)}{\sin\theta}$$

$$\cot\phi = \frac{\left(\frac{\Delta\lambda}{\lambda}\right) + (1 - \cos\theta)}{\sin\theta}$$

$$\Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$\cot\phi = \frac{\frac{h}{m\lambda c}(1 - \cos\theta) + (1 - \cos\theta)}{\sin\theta}$$

$$\Rightarrow \cot\phi = \left(\frac{1 - \cos\theta}{\sin\theta}\right)\left(\frac{h}{m\lambda c} + 1\right)$$

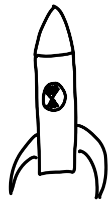
$$\cot\phi = \frac{\left(\frac{1 - \cos(\theta/2)}{2}\right)}{2\sin(\theta/2)\cos(\theta/2)}\left(1 + \frac{h}{m\lambda c}\right)$$

$$\cot\phi = \frac{\left(2\sin^2(\theta/2)\right)}{2\sin(\theta/2)\cos(\theta/2)}\left(1 + \frac{hc}{m\lambda c^2}\right)$$

$$\cot\phi = \frac{\sin(\theta/2)}{\cos(\theta/2)}\left(1 + \frac{hf}{mc^2}\right)$$

$$\boxed{\cot\phi = \tan\left(\frac{\theta}{2}\right)\left(1 + \frac{hf}{mc^2}\right)}$$

Problem 59

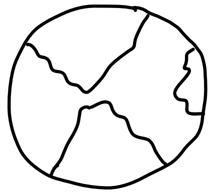


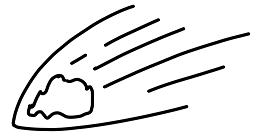
$E=mc^2$

Amihilation

$\therefore E = 2mc^2$

$U = \frac{1}{2}\frac{GM_E^2}{R_E}$





$\rho = 5.0\times10^3\ kg/m^3$

5000 MT

$1\ MT = 4.2\times10^{15} J$

$E = 2.1\times10^{19} J$

Annihilation : Electron and Proton $\therefore$

$E = 2mc^2$ $\quad E = \frac{1}{2}\frac{GM_E^2}{R_E}$

$M_E = 5.972\times10^{24}\ kg$

$R_E = 6371\times10^3\ m$

$G = 6.67\times10^{-11}\ \frac{Nm^2}{kg^2}$

$2mc^2 = \frac{1}{2}\frac{GM_E^2}{R_E}$ $\qquad m = \frac{GM_E^2}{4R_Ec^2}$

$$m = \frac{(6.67\times10^{-11}\frac{Nm^2}{kg^2})(5.972\times10^{24}kg)^2}{4(6371\times10^3 m)(3.0\times10^8 m/s)^2} = 1.037\times10^{15}\ kg = 1.04\times10^{15}\ kg$$

Presuming it is spherical in shape :

$\rho = \frac{m}{V}$ $\therefore$ $V = \frac{m}{\rho}$ $\qquad V = \frac{4}{3}\pi r^3$

$\rho = 5.0\times10^3\ kg/m^3$

$m = 1.04\times10^{15}\ kg$

$\frac{4}{3}\pi r^3 = \frac{m}{\rho}$

$\pi r^3 = \frac{3}{4}\frac{m}{\rho}$ $\qquad r = \sqrt[3]{\frac{3(1.04\times10^{15}kg)}{4\pi(5.0\times10^3 kg/m^3)}} = 3{,}675.57\ m$

$r^3 = \frac{3m}{4\pi\rho}$ $\qquad r = 3.68\ km$

$r = \sqrt[3]{3m/4\pi\rho}$

Comparing with nukes

$$U = \frac{0.5\,GM_E^2}{R_E} = \frac{1}{2}\frac{(6.67\times10^{-11}Nm^2/kg^2)(5.972\times10^{24}kg)^2}{(6371\times10^3 m)} = 1.867\times10^{32} J$$

$E = 2.1\times10^{19} J$ $\qquad N = U/E = \frac{1.867\times10^{32}J}{2.1\times10^{19}J} = 8.89\times10^{12}$ equivalent nuke arsenals

$\boxed{\begin{array}{ll} r = 3.68\ km & 9.0\times10^{12} \text{ equivalent nuke} \\ m = 1.04\times10^{15} kg & \text{arsenals} \end{array}}$

Problem 60

$$KE = \frac{\left(\frac{\Delta\lambda}{\lambda}\right)}{1+\frac{\Delta\lambda}{\lambda}} hf$$

i.)

$$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$

$$\lambda' - \lambda = \frac{h}{mc}(1-\cos\theta)$$

$$\lambda' = \lambda + \frac{h}{mc}(1-\cos(\pi))$$

π or 180 creates max

$$\lambda' - \lambda = \frac{2h}{mc}$$

$$\Delta\lambda = \frac{2h}{mc}$$

$$\Delta\lambda = \frac{2hc}{mc^2}$$

$$\frac{\Delta\lambda}{\lambda} = \frac{2hc}{m\lambda c^2} \Rightarrow \frac{\Delta\lambda}{\lambda} = \frac{2hf}{mc^2}$$

$$\boxed{KE = \frac{\left(\frac{2hf}{mc^2}\right)}{1+\frac{2hf}{mc^2}} hf}$$

max at $\theta = 180° \Rightarrow \phi = 0°$

ii.) $KE = hf - hf'$

$$\frac{\frac{2hf}{mc^2}}{\frac{mc^2+2hf}{mc^2}}$$

$$\frac{2hf(mc^2)}{(mc^2)(mc^2+2hf)}$$

$$hf\left(\frac{2hf}{mc^2+2hf}\right) = \left(\frac{2hf}{mc^2}+1\right)hf$$

$$KE = \left(\frac{2x}{mc^2+2x}\right)x \qquad x \equiv hf$$

$$KE(mc^2+2x) = 2x^2$$

$$KEmc^2 + 2xKE = 2x^2$$

$$2x^2 - 2xKE - KEmc^2 \qquad m = 0.51100 \frac{MeV}{c^2}$$

$$x^2 - xKE - \frac{KE}{2}mc^2$$

$$x^2 - 100\,\text{keV}\,x - 25{,}550\ \text{KeV} = 0$$

$$x = -117.3\ \text{keV} \text{ or } 217.3\ \text{keV}$$

$$hf = 217.3\ \text{keV}$$

$hf' = hf - KE$ — hf' denotes scattered particles

$$hf' = 217.3\ \text{keV} - 100\ \text{KeV}$$

$$hf' = 117.3\ \text{keV}$$

$$\boxed{hf' = 117.3\ \text{keV}}$$